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Code-Regenerative Clean-Up Loop for a Ranging Transponder

The range from a ground tracking station to a spacecraft is determined by measuring the round-trip time required for a ranging code sequence signal to be transmitted from the station to the spacecraft and transponded back to the ground station. In typical spacecrafts, the ranging transponders demodulate and limit the received ranging signal and then re-modulate it onto an rf carrier of a different frequency for retransmission to the Earth. A major drawback of such transponders is that the signal received at Earth contains the noise in the signal received by the spacecraft as well as the noise in the spacecraft's receiver and transmitter, together with any noise superimposed on the transponder signal, during its journey to Earth. Whenever the up-link ranging channel signal-to-noise ratio (SNR) is below unity, most of the down-link ranging power is wasted on noise rather than on the ranging signal.

A digital processing system has been developed to regenerate the ranging signal in the spacecraft for transmission to the ground. The system, called Clean-Up-Loop, phase locks on the received ranging signal and generates a clean replica of the received ranging code. The regenerated ranging signal has no amplitude noise, except for a small amount of phase jitter, corresponding to the phase error in the phase-locked regeneration loop; the phase noise can be averaged out at the Earth receiver. Because the regenerated signal is clean, the increase in down-link SNR is approximately equal to the ratio of up-link receiver noise to signal.

The clean-up-loop is designed to operate in conjunction with a binary coded sequential-code-component ranging system (μ -system) rather than with a

parallel component pseudonoise (PN) system. In the μ -system, square waves at successively lower frequencies are transmitted sequentially; first, the range is measured at high resolution, but with 2-microsecond ambiguities, using a 500-kHz square wave; then, a 250-kHz square wave is transmitted so as to eliminate half of the ambiguities. Lower and lower frequencies are transmitted until all ambiguities are resolved. The clean-up-loop transponder operates by phase-locking on each code component frequency as it is received by the spacecraft; a square wave in phase with the received signal is generated for modulation onto the down-link carrier for transmission to Earth. Operationally, the first square-wave frequency is transmitted for a time long enough for the clean-up-loop to acquire frequency and phase lock, then the transmitter switches to another frequency, etc.; the clean-up-loop must determine when the received signal changes the frequency of its square wave component, and then it must change the phase-locked loop reference signal to track the new component.

A detailed report is available which systematically records the results of a mathematical analysis of the Clean-Up-Loop system; the report also includes a summary of experimental tests.

Notes:

1. Although the Clean-Up-Loop system has been devised expressly for deep space work, the system (or many of its technical aspects) is broadly applicable to a variety of terrestrial ranging problems, including oceanic navigation.
2. Requests for further information may be directed to:

(continued overleaf)

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(NPO-11707)